WOOD ASH IN CONE SIX GLAZES

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PREFACE

The development of ceramic glazes has an interesting history of accidental discovery which dates back to at least 5000 B.C. The processes involved in glaze making were simple enough and the basic raw materials were in abundance, resulting in glaze developments in many parts of the world long before the beginning of scientific knowledge of chemistry.

The basic materials consisted simply of a flux (a metalic oxide), such as sodium or potassium, which would facilitate the melting of heat resistant silica and alumina into glass. Since these two oxides and silica and alumina make up about 75 per cent of the earth's crust as constituents of clays, sand, feldspars and igneous rock, they were available to all people and their usefulness needed only chance discovery.

The Egyptians were first to make the discovery. Their first glazed objects were small ornaments carved from steatite, a soft talc rock. When these ornaments were fired, the talc constituents, magnesium and silica, fused to produce a glaze. It is known to this day as Egyptian paste. Later, pulverized sand, soda ash, and clay were mixed with water and applied to finished ware to produce an even glaze coating in much the same way that it is now done. Additions of copper bearing minerals to this glaze produced blue and turquoise colors.

By 1000 B.C. the Syrians and Babylonians made a further glaze advancement by discovering the usefulness of lead compounds for fluxing agents. The use of lead for a glaze flux slowly spread throughout Europe.

China's potters perfected kilns that could reach higher temperatures than those being used elsewhere. Because of their geographic and cultural isolation they were able to guard this discovery from the rest of the world for nearly 2000 years. Some of the natural clays were found to be fusible at the higher temperatures, readily forming glassy surfaces without additional flux. Pulverized feldspathic rock was found also to be a glass former, as were the ashes from weeds, straw, and wood.

The appearances of ash-glazed pottery in the high-fire kilns resulted when wood ash from the fire boxes was drawn through the kilns and over the ware by the hot air drafts. Some of the ash deposited on the sides of the pottery and there melted into thin glaze. Proceeding by trial and error, experiments with various combinations of available ashes, clays, lime, and petuntze (a feldspathic rock resembling Cornwall stone) produced a variety of durable and beautiful glazes.

Much of the appeal that ashes have as a glaze ingredient comes from the fact that wood ash is a natural and abundant material. Ashes do not require mechanical or industrial processing, offering one a rather rare encounter with a raw material. Ash glazes have a distinctive quality and appearance that cannot be produced with other glaze chemicals. But the use of ash is rewarding also because of the satisfaction that comes from producing something beautiful from common materials and from learning to control glaze by personal experimentation.

This study has revealed the usefulness and beauty inherent in a material that is not known to many; and perhaps that has been some of the reason for the pleasure derived from this study. Also, there is something exciting, and urgent perhaps, about leaving man's world of ready-made products. In our time the experience of cutting and burning wood, processing ash, and the experimenting that leads to the finished glazes are themselves of an aesthetic nature.

An acknowledgement of my gratitude and indebtedness are here made to Professor Arthur E. Smith, Head of the Department of Art and to Professor Glenn C. Nelson, my ceramics instructor. Their considerations have made possible the opportunity for graduate study during the 1966 school year.

CHAPTER I

MINERAL COMPOSITION OF SOIL AND PLANTS

The mineral compounds found in a plant's ashes are directly related to the soil from which the plant is produced. These compounds include phosphates, sulphates, carbonates and chlorides, magnesia, lime, soda, potash, manganese, lime, sodium potassium, iron, silica, lithia, alumina and the oxides of metals such as lead, zinc, titanium, and copper.

A break-down of the major chemicals as they compose the world's crust follows:[1]

Silica	59.14%
Alumina	15.34
Iron	6.88
Calcium	5.04
Sodium	3.85
Magnesium	3.49
Titanium	1.05

These percentages are not, of course, constant in every soil. There is considerable loss of particular minerals through leaching and there are additions through organic accumulations. In this regard studies have shown alumina, iron, and titanium to be the most durable of the minerals.[2] The bases; calcium, sodium, magnesium, and potassium

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[1] Daniel Rhodes, Clay and Glazes for the Potter, (New York: Chilton Company, 1957), p. 5.

[2] C. A. Black, Soil and Plant Relationships, (New York: Wiley, 1957), p. 12.

are readily leached out of soil. As a result many of the world's old soils have been reduced to agriculturally useless compositions. Bauxite, from which aluminum is mined, may be all that is left of a soil after millions of years of leaching.

Every plant requires a certain minimum of each mineral nutrient. In most cases, besides this minimum, plants assimilate any available excess of the various compounds along with other substances which are perhaps useful but not essential to their functions.

Plants which have a more intense rate of transpiration contain more ash than those plants with lesser rates. Cabbage leaves, being 90 per cent water, contain 15-18 per cent ash while the leaves of potatoes, clover, and grass, having 80 per cent water contain only six to nine per cent ash. Similarly, the leaves of trees adapted to moist soil (poplar, maple, and basswood) contain more ash than do the leaves of trees in which transpiration goes on more slowly, such as in oaks and pines. The leaves of most trees show four per cent of ash and higher, but the needles of pine trees show less than one per cent.

The highest ash percentage occurs in the leaves of the plant and decreases significantly through the roots, stems, and seeds. The trunk of the tree shows the lowest percentage. The heart wood of the trunk has less than the outer growing layers.

Vegetable matter is about 60 per cent cellulose. This plus lignin, the plant's binding material, and its water are driven off or are given to combustion when the plant is burned, leaving only the inorganic mineral compounds that were dispersed throughout the plant. Some of the sulfur and phosphorus and all of the nitrogen are lost during combustion. The ash that remains from a wood fire is a quantity of unknowns, a complex deposit of as many as twenty or more minerals.

Minerals such as calcium, potassium, sodium, and magnesium act as fluxes in glaze because of their low melting points. The oxides of copper, iron, titanium, and cobalt effect the glaze color while the alumina and silica content largely determine the fluidity of a given ash glaze.

CHAPTER II

COLLECTING AND PROCESSING ASH

Securing a quantity of ash to use in glaze can be time consuming as one may have to cut, split, and burn 100-200 pounds of wood to produce even one pound of ash. Fireplaces seem to be the most logical source of ash. From this source the energy for wood gathering and cutting has been expended for the heat product and the ash becomes a bonus in by-product. If, on the other hand, the same energy is put to an outdoor fire, the heat potential is negated, thereby raising the "cost" of the ash.

Burning outside produces problems in collecting the maximum ash from a given fire since even a mild wind can blow the lighter ash particles away. A large fire must be allowed to burn for many hours following the heaping on of wood in order to give the coals time to burn to white ash. This necessitates leaving the ash out overnight and it puts one's efforts at the mercy of weather change. The author has given up an entire day's work to seventeen inches of wet snow, and the threat of rain has since made special trips to smoldering ash piles necessary.

One other disadvantage with outdoor fires is that the ash is usually collected along with sand, stones, and debris. The latter are easily sieved out but some of the fine sand particles pass through the sieves and they are apt to form scattered rough spots in the fired glaze, being too large to be completely melted. If one has to burn outdoors it is therefore a wise precaution to procure sheet metal of some sort on which to build the fire. Two discarded metal culvert intakes placed mouth to mouth made an ideal burner for my own wood fires. In the fall many piles of leaves are left burning along the city streets and a little observation may pay off in large quantities of work-free ash at such times. Since leaves contain high percentages of potash and magnesium their ash melts freely in glaze, forming surfaces that are beautifully smooth and colorful.

After the ashes from a fire have cooled they should be sieved through a one or 1/2 inch mesh to remove unburned materials and charcoal. An intermediate sieving should then follow with about a 1/8 inch mesh; and finally the ash should be hand rubbed through a #60 mesh. (The hand rubbing action forcibly grinds and breaks up the loosely fused particles which will have formed in a hot fire.) Those ash grits which will not pass through the #60 mesh are useless. Some of the sandy-textured ashes, tamarack and burr oak, for example, need an additional sieving through a finer mesh. (These two ashes were ground in the ball mill to render them fusible but the additional work was not compensated for by any unusual qualities.)

Traditionally ashes are put through a soaking and rinsing cycle to remove the water-soluble fluxes which irritate the hands and sometimes cause raw-glazed pottery to crack. The washing procedure is to mix an excess of water with the ash in a receptacle and remove the charcoal that floats on the surface. Then the mixture is decanted into a second container, leaving any sand or grit at the bottom of the first receptacle. Additional flooding, soaking, and draining will eventually remove all of the soluble sulphates, chlorides and potash. Usually soaking and draining the ash twice is sufficient to reduce it to a noncaustic state but if the water from the second soaking is strongly discolored an additional washing may be necessary. At any rate, if the water and ash are allowed to stand overnight the greater part of the soluble minerals can be removed in the first decanting.

CHAPTER III

TESTING FOR ASH QUALITIES

Ashes are not generally useful by themselves for glazing purposes, since they normally melt into a very thin coating which tends to craze badly. Instead ashes can be added to proven glazes in amounts of from 10-35 per cent. If larger percentages are used for cone six glazes, additional flux will probably be needed to melt the over-load.

The best way to get glaze results from new ashes is to keep several glazes dry-mixed so that experiments can quickly and easily be made when ash becomes available. The glazes that have been used throughout this study include mat and transparent bases which contain either feldspars, nepheline syenite, dolomite or spodumene. (All but glaze "A" are good without ash additions.) Twenty-seven per cent of each ash was added to each of these bases despite the fact that some of the results would have been better with either more or less than this percentage. The result was that of the 175 possible combinations of glaze bases and types of ash about 60 were compatible enough to be considered as useful results. That is an average of one good combination for every three attempts.

All of the combinations could be made to work by altering the base formulas to make the ash additions "fit", but it is, undoubtedly, less trouble and effort to try several existing glazes with the ash and pick the successful combinations for use. Table II of particular ash characteristics should be helpful in eliminating guess work and its use should insure a better percentage of success.

Bernard Leach[3] has grouped ashes into quantitative types, labeling them hard, medium, and soft. The degree of "hardness" or "softness" was arrived at by mathematically totaling the percentages of the fluxes (lime, potash, and magnesium) in each ash. This total was subtracted from the ash's total percentage of alumina, silica, and phosphorus. If the remainder was high (79 in the case of rice straw ash) the ash was considered hard. A higher temperature would be required to melt the hard ashes and the soft ashes would melt relatively easily. Medium ashes on this scale are those which lie between 40 and -20. The soft ashes were considered as such at -20 and lower. These resulted from low silica-alumina totals and very high flux totals. Excerpts from Leach's work appear in Table I on the following page.

With very incomplete and often contradictory chemical analysis of local woods available, it was not possible to arrange local wood and leaf ash into such a mathematical scale of hardness. However, the glaze tests readily indicate the observable nature of the woods general chemical properties in regard to ratios of flux to alumina and silica. It is possible to look carefully at the tests and arrange the glazes into a relative hardness order. Of course, the latter method is not as accurate as the method Mr. Leach devised but it is

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[3] Bernard Leach, A Potters Book, (Hollywood-by-the-Sea, Florida: Transatlantic Arts Inc., 10th Edition 1965), p. 162.

good enough for practical purposes and it does eliminate the expense of quantitative chemical analysis.

Description	Silica	Alumina	Phosphorus	Iron	Lime	Potash	Magnesia	Carbonate	Sulphate	Chloride	Hard	Medium	Soft
Japanese rice straw ash, fully washed	77.68	9.11	0.90	2.93	4.00	1.68	2.44	0.96	-	-	79		
Japanese isu ash, fully washed	71.96	0.63	0.42	0.28	15.95	0.84	1.57	8.29	-	-	54		
Thatching reed ash, fully washed	51.10	12.90	6.28	2.42	13.15	3.12	4.41	6.47	-	-	49		
Mixed autumn weed ash, unwashed	56.45	4.31	2.57	1.17	18.10	2.73	5.32	8.11	1.05	0.06		37	
Ditto, fully washed	57.47	4.26	2.15	1.18	18.81	1.66	6.05	8.29	-	-		37	
Apple pulp ash, once washed	33	22	13.42	1.53	11.15	9.26	4.56	5.46	-	-	43		
Ditto, unwashed	27.76	21.48	11.14	1.18	6.95	15.50	6.43	5.59	3.21	0.10		31	
Lawn mowings ash, once washed	39.64	16.60	9.00	3.44	12.88	6.19	5.65	6.20	-	-	40		
Ditto, unwashed	30.16	12.43	7.90	2.37	7.83	17.55	5.39	7.58	3.50	4.94		19	
Bracken ash, fully washed	40.37	11.97	4.43	0.72	20.61	2.35	10.90	8.26	0.23	0.16		22	
Ditto, once washed	40.59	9.42	3.98	0.82	20.38	3.40	10.55	9.33	0.82	0.71		19	
Box ash, fully washed	14.29	10.34	4.73	2.74	37.55	2.58	6.12	21.49	-	-		-17	
Apple wood ash, once washed	2.65	1.98	1.59	0.70	54.20	0.89	3.25	34.69	-	-			-52
Wheat husk ash	68.53	4.44	2.23	4.46	7.23	8.03	1.88		8.03	8.03	58.06		

TABLE I

PIGMENTS AND GLAZES

CHAPTER IV

RESULTS OF GLAZE EXPERIMENTS

Glaze "A" of the test tiles which were made in conjunction with this study uses 50 per cent of each ash with 45 per cent feldspar and 5 per cent colmanite. The quality of the surfaces are imperfect enough to appear pleasantly rugged in most cases but without the addition of clay (kaolin) to the formula many of the glazes were disturbingly thin. Gray birch (3A) formed the best surface with this glaze base. Others, elm (10A), silver maple (13A), red pine (19A), and white spruce (23A) are useable surfaces that would best be applied thickly. Several of these showed an opacity only in those areas where the glaze was applied thickly. Experiments with clay additions with this base would show good results and since the formula calls for 50 per cent ash and 45 per cent feldspar it would be an inexpensive glaze.

Fig. 1

Glaze "B" is a potash feldspar ($K_2O \cdot Al_2O_3 \cdot 6SiO_2$) whiting ($CaCO_3$) base high in silica which gave rather disappointing results with most of the ashes. All of the hard ashes and some of the mediums used here produced "sandpaper" surfaces as a result of excessive silica and alumina accumulation produced by combining both the highly silacious glaze and ash. These include ash wood (1B), elm (10B), sugar maple (15B), burr oak (17B), aspen (20B) and balsam poplar (21B). This seems to be a reasonable conclusion in view of the fact that the soft ashes with their low silica-alumina compositions melted to smooth surfaces. The leaf ash of birch (4B), cotton wood (8B),

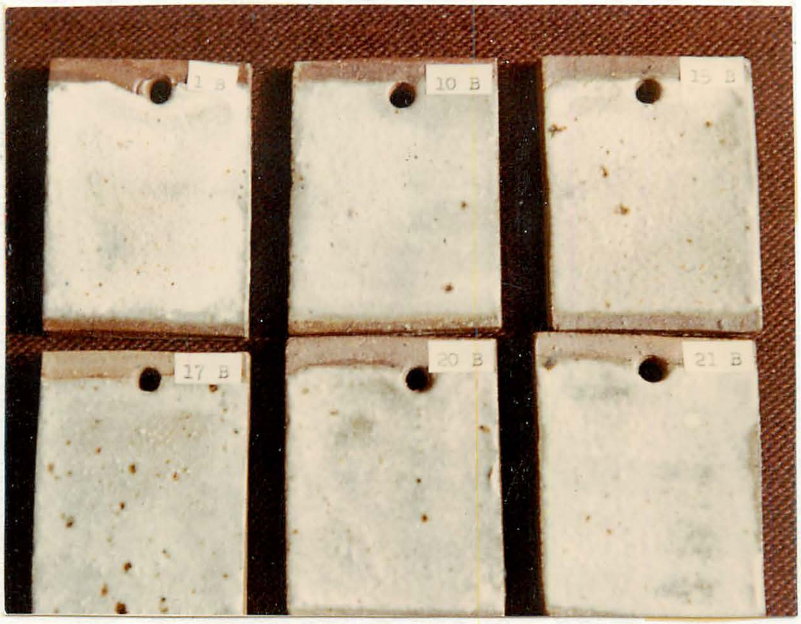


Fig. 2

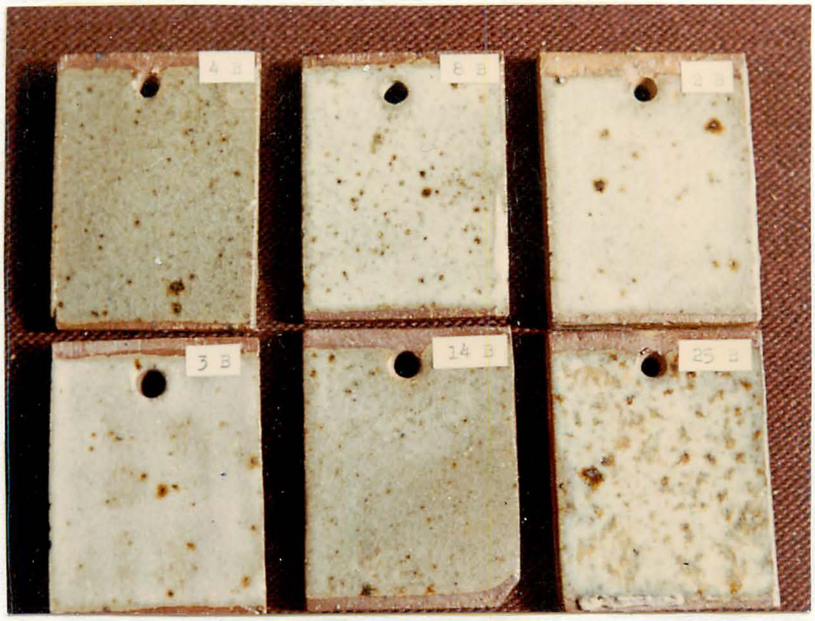


Fig. 3

paper birch (2B), gray birch (3B) and maple (14B) were most compatible. Rather spectacular dappling occured in the willow wood (25B) and in the cotton wood leaf; the apparent result of titanium or manganese gatherings in the original plant.

Glaze "C" is a dolomite ($CaMg\ (CO_3)_2$) semi-mat white glaze with a stiff quality that perhaps served best to indicate the various hardnesses of the ashes that were used. In this base the soft ashes of red pine (19C), white pine (18C), white spruce (23C), and silver maple leaves (14C) melted to a very smooth surface, their high flux percentages contributing to the fusion of the ingredients. Medium ashes from gray birch (2C), blue spruce (22C), balsam poplar (21C), and willow (25C) were rather neutral, neither melting nor

Fig. 4

stiffening the base significantly. The harder ashes from ash wood (1C), elm (10C), aspen (20C) and silver maple (13C) roughened the surface considerably, indicating higher silica and alumina counts than the other ashes.

Glaze "D" is a mat nepheline syenite ($K_2O \cdot 3Na_2O \cdot 4Al_2O_3 \cdot 9SiO_2$) base which tended to produce yellow and brown colors. The five leaf ashes (D4, 8, 9, 14 and 16) and the cob ash (D6) all made exception, however. They tended toward grayish, bluish, and yellowish shades of green. The possible reason for these exceptions is that leaves and cobs have higher iron contents than the woods. (Ashes of leaves and cobs also produced the purest green with the Cornwall base, glaze "F" and "G").

Fig. 5

Unusual patterns of color streaks and mottling occurred in several of these glazes, running down the tiles and around the iron spots like currents of water around the rocks in a stream bed. Nearly all of these combinations were good. Willow (25D), walnut (24D), white and blue spruce (23, 22D), aspen (20D), and white pine (18D) are shown.

Fig. 6

Glaze "E" is a spodumene ($Li_2O \cdot Al_2O_3 \cdot 4\ SiO_2$) base that is in itself runny and greenish in color. Here there was great similarity in the color and texture from one ash to another. The lithia in the spodumene imposed its own green color rather thoroughly on each ash. But the small golden iron crystals that developed readily in some of these runny glazes offer enticement to explore the crystaline possibilities of the hard ashes of maple (13E), elm (10E), and ash (1E). Aspen (20E) and balsam poplar (21E), two locally abundant woods, were at their best in the spodumene base. Red pine (19E) is also shown.

Fig. 7

Rows "F" and "G" use the same Cornwall base - "G" being applied over white porcelain tiles. This base, being similar in composition to the feldspathic "petuntze" glazes used by the ancient Chinese, gives glaze qualities which are of special interest. The base is extremely clear in itself but the ash effects are wonderfully varied. The desirable mat and semi-mat surfaces were produced by nearly one-half of the ashes when they were applied in glaze over the stoneware (row "F") tile. A wide variety of muted colors resulted. Especially intriguing is the possibility of using some of these glazes over slip-decorated stoneware pottery to achieve the same color contrasts that exist between the stoneware and porcelain tiles. Silver maple ash, for example, is a pale yellowish-gray over stoneware (13F) that becomes a gold-spattered pure white over porcelain (13G). Ash wood (1F, 1G) shows prominent contrast also.

The crazing tendency of the ash glazes also is put to good use on the porcelain body, for the crackle pattern becomes more visible over the white ground. A beautifully fine crackled celedon green was produced by the cottonwood leaf ash (8G) in particular.

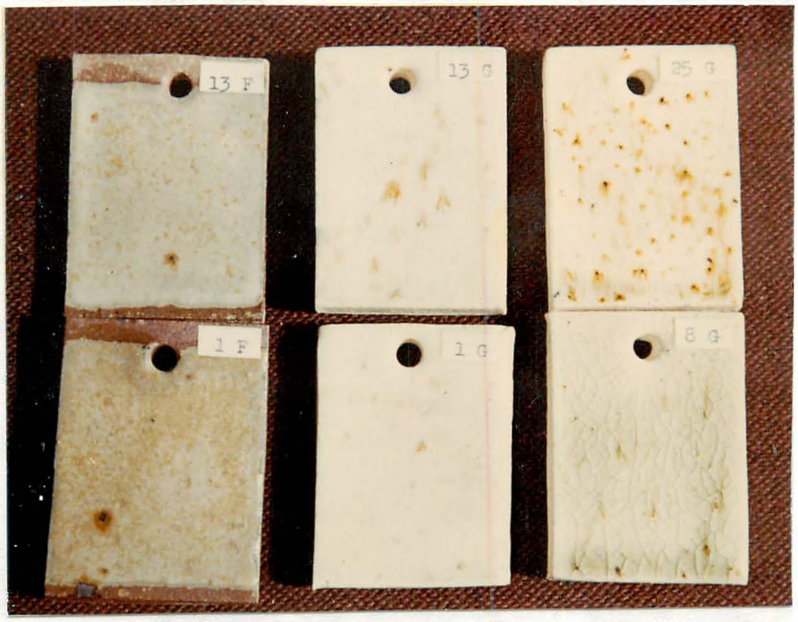
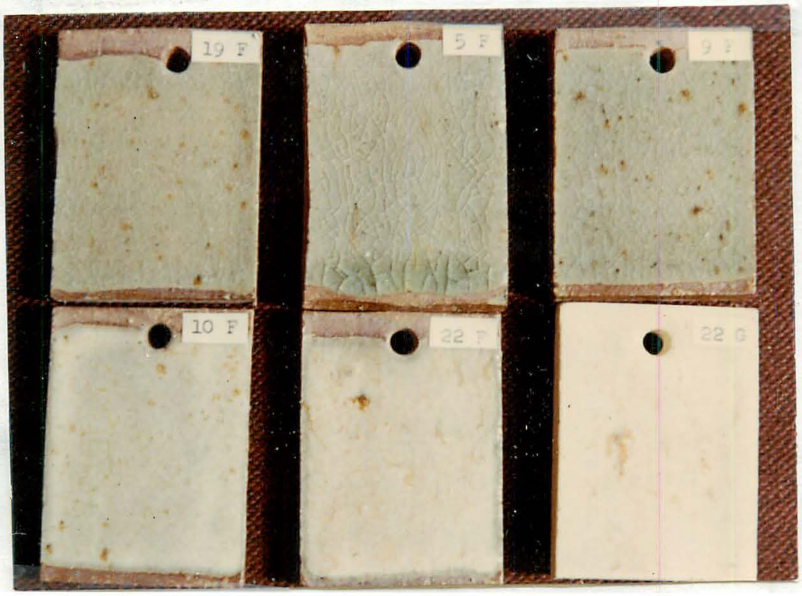


Fig. 8

Although several of the combinations in glaze "F" remained clear there were slight color differences among them. The base became grayed or greenish with the ash additions, usually developing a fine crazing in the process. Also small brownish spots or speckles often appeared as in willow (25G), red pine (19F), box elder (5F), and elm leaf (9F). As expected the softer ashes permitted the clear tendency while the harder ashes caused the semi-opaque and opaque glazes. Ash wood (1F), elm wood (10F), and blue spruce (22F and G) are very opaque.

Fig. 9



CHAPTER V

CONCLUSIONS

Glazes exist as rather delicate balances of flux, alumina, and silica. These three-element combinations can be compounded in numberless ratios which will, in turn, produce numberless glaze textures and colors. The intrigue of working with vegetable ash as a glaze ingredient is that each ash exists as an unknown ratio of these elements. Different ashes may produce glazes that are oily smooth in surface or dry and mat. They may be transparent or completely opaque; range in color from whites, browns, and yellows to grays and greens, being finely speckled, heavily spotted, mottled or streaked.

The composition of any plant's inorganic chemicals (ash) is dependent upon the soil from which the plant grows. If the soil is high in iron the ash from its plants will have a high iron content also. Plants assimilate all soil ingredients whether they are vital to the function of the plant or not; but, of course, most of the soil's constituents serve as plant nutrients.

In regard to soil composition, rather consistent results were produced by ash from like woods which were taken from different locations. The differences in three samples of ash wood and in three of birch wood showed only negligible differences in surface and color; and those slight differences may have been due to the fortunous aspects of separate firings. All of the repeat tests were made on woods from the Duluth area, though, and undoubtedly trips further afield to different types of soils would see some changes in chemical content which would result in the color and texture change of glazes.

Readers who may be interested in working with ash glazes will find Table II helpful in deciding which ashes might most successfully be used with particular glaze bases. "Hard" ashes are those which tend toward opaque mat surfaces because of high silica-alumina counts. The "soft" ashes have higher percentages of fluxes.

ASH	QUALITY		% ASH IN DRY WOOD [4]
Ash wood	hard	opaque	.43
Paper birch	medium	semi-opaque	.24
Paper birch leaves	soft	clear	-
Gray birch	medium	semi-opaque	.35
Box elder	medium soft	clear	-
Cedar	medium hard	semi-opaque	-
Corn cobs	medium	clear	-
Cottonwood leaves	medium soft	clear	-
Elm	hard	opaque	.81
Elm leaves	soft	clear	-
Fir	medium soft	semi-opaque	.23
Larch	medium hard	clear	.17
Silver maple	medium hard	opaque	.33
Silver maple leaves	soft	clear	-
Sugar maple	medium hard	semi-opaque	.54
Burr oak	hard	semi-opaque	.71
Red oak leaves	medium	semi-opaque	4.70
Balsam poplar	medium hard	semi-opaque	1.05
Poplar (Aspen)	medium hard	semi-opaque	.26
Red pine	soft	clear	.27
White pine	soft	clear	.19
Blue spruce	medium	opaque	-
White spruce	medium soft	semi-opaque	.31
Walnut	hard	semi-opaque	.79
Willow	medium soft	clear	2.80

TABLE II

4 Charles Sargent, Report on the Forests of North America (Boston: Houghton, Mifflin & Co., 1943), Vol. 9, p. 5.

Results will generally be best if the hard ashes are added to fluid bases and if the softer ashes are added to stiff or mat bases. The medium ashes are more tolerant than the mentioned extremes, hard and soft.

Generally ashes that are hard will not work well in a stiff or mat base. Soft or medium-soft ashes work well in most of the bases, whether the base is stiff or runny. Good examples of hard ash and fluid glaze combinations that worked well together were the ash, elm, and maple additions to the cornwall base (Fig. 9). The tiles of these three ashes were very similar in both color and texture, all having reduced the shiny Cornwall base to a very pleasant mat.

Soft ashes can be used in fluid glazes without causing excessive running, but many of the hard ash glazes that appear on the test boards are too stiff to be useful as they are (Fig. 2). Additions of fluxing chemicals could be made in order to render them useful.

There is general similarity of glaze effect produced by ashes within a family of trees. Red and white pine showed like characteristics; as did silver and sugar maple, gray and paper birch, white and blue spruce, and aspen and poplar. Knowing one or perhaps two trees of a given family should allow for quite a good guess as to the nature of the others in the same family. Jack Pine was not used in this study but it probably has soft ash and the clear tendency. Red maple was not used but it is probably very similar in chemical analysis and glaze effect to silver and sugar maple. The most locally abundant trees have their ash qualities described in Table II.

Lepidolite was also used for a base, but the results are not shown on the test board or in any of the photographs. Its effect on the ashes was similar to that of spodumene (Fig. 7) in that the base's color prevented color contributions from the ashes. Both of these bases were, perhaps, too fluid for the twenty-seven per cent ash additions. More varied results would be achieved by adding larger amounts of ash to such bases.

Again, all of the ash and base combinations could be made to give good results by altering the base formula to "fit" the ash addition but it is far less trouble and effort to try several existing bases with the ash and pick the successful combinations for use.

Perhaps more could be said about results but readers are referred to the original test boards which are now the property of the ceramic studio. The actual tile would prove helpful to others who are interested in working with ash glazes.

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